

RESPONDING CHANGES SYSTEMATICALLY WITHIN SESSIONS DURING CONDITIONING PROCEDURES

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When the procedure is held constant within an experimental session, responding often changes systematically within that session. Many of these within-session changes in responding cannot be dismissed as learning curves or by-products of satiation. They have been observed in studies of positive reinforcement, avoidance, punishment, extinction, discrimination, delayed matching to sample, concept formation, maze and alley running, and laboratory analogues of foraging, as well as in the unconditioned substrates of conditioned behavior. When aversive stimuli are used, responding usually increases early in the session. When positive reinforcers are used, responding changes in a variety of ways, including increasing, decreasing, and bitonic functions. Both strong and minimal reinforcement procedures produce within-session decreases in positively reinforced behavior. Within-session changes in responding have substantial theoretical and methodological implications for research in conditioning.

Key words: positive reinforcement, discrimination, concept formation, delayed matching to sample, avoidance, punishment, unconditioned behavior, warm-up effects, within-session changes

Psychologists often study measures of behavior that are averaged across experimental sessions (e.g., Herrnstein, 1970). The use of average measures (e.g., accuracy, latency, rate of responding) rests on the assumption that responding does not change systematically within the session. If there are such systematic changes, then average measures will obscure potentially significant variations in behavior at a more molecular level.

In the past, within-session changes in responding have been tacitly acknowledged, but they usually have been treated as problems to be controlled, rather than as phenomena to be studied. For example, animals may be given some time to adapt to the apparatus before the experiment is conducted (e.g., autoshaping, Papini & Overmier, 1985; avoidance, Katzev & Mills, 1974; conditioned emotional response procedures, Wheatley & Welker, 1977; consummatory responding, Couvillon & Bitterman, 1985; escape, Drugan & Maier, 1983; habituation, Davis, 1974a, 1974b). Animals may also be given warm-up trials before data are collected (e.g., animal psychophysics, Hodos & Bonbright, 1972; avoidance, Neffinger

& Gibbon, 1975; categorization, Jitsumori, Wright, & Shyan, 1989; classical conditioning, Mineka & Gino, 1979; delayed matching to sample, Edhouse & White, 1988; discrimination, Alvarado & Rudy, 1992; generalization, Griffin & Stewart, 1977; Thomas, 1981; Thomas & Burr, 1969; list learning, Schwartz, Chen, & Terrace, 1991; and punishment, Bolles, Holtz, Dunn, & Hill, 1980). Presumably, adaptation time or warm-up trials are given because responding during the early part of the session differs from later responding.

More recent evidence suggests that systematic changes in responding may occur throughout the entire session and may be worthy of study in their own right. For example, McSweeney, Hatfield, and Allen (1990) reported that response rates increased to a peak and then decreased within sessions when rats' lever pressing was reinforced with Noyes pellets and when their key pressing was reinforced with sweetened condensed milk. Several characteristics of these within-session changes suggested that they deserve study. First, the changes were as large as, or larger than, those attributable to variables that are commonly manipulated in experimental analyses. For example, Catania and Reynolds (1968, Experiment 1) observed a doubling of response rate when they changed the programmed rate of reinforcement from 8.4 to 300 reinforcers per hour. The rate of key pressing reported by McSweeney et al. changed by an average of 450% within the sessions. Second, the changes were reliable, occurring for each individual subject

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during each session (McSweeney & Hinson, 1992). Third, the changes were orderly. The within-session changes in responding peaked at the same time in the session for all subjects for both types of response and reinforcer. Finally, the changes occurred in spite of, rather than because of, the programmed distribution of reinforcement. That is, the multiple variable-interval schedules used by McSweeney et al. presented a constant, not a changing, programmed rate of reinforcement within the session.

The present paper presents gleanings from the literature on conditioning that provide additional evidence that responding changes systematically within experimental sessions. Such a review may help to determine the generality and, therefore, the importance of these changes. If changes occur only under limited conditions, then they would reflect processes peculiar to those conditions; if they occur more generally, they may have fundamental theoretical and methodological implications.

A systematic review may also clarify the factors that produce within-session changes in responding. Increases in responding early in the session are often attributed to "warm-up." Later decreases may be attributed to "satiation." However, many variables may actually contribute. Potential explanations for the increases in responding include: A response that interferes with instrumental responding might occur early in the session and then disappear (e.g., Bindra, 1959; Feldman, 1963; Glanzer, 1958). Subjects may require time to recover from the handling routine that places them in the chamber. Subjects may require time to establish a "set" for responding, defined in terms of peripheral postural adjustments or in terms of a central focusing of attention (e.g., Ammons, 1947; Irion, 1948). Subjects may have to recover from the "information overload" evoked by a new environment (e.g., Richardson & Campbell, 1992). Some experience may be required for the subject's memory of the task to be reinstated (Spear, 1973). The presentation of reinforcers may produce arousal that accumulates gradually over the session (e.g., Hoffman, Fleshler, & Chorny, 1961; Killeen, Hanson, & Osborne, 1978). Finally, priming may occur. That is, the reinforcer may gain strength with repeated exposures (e.g., Olds, 1956). Potential explanations for within-session decreases in responding include the fol-

lowing: Subjects' muscles may become fatigued (e.g., Mosso, 1906); a central process such as attention may wane because of underload (e.g., boredom, J. Mackworth, 1968) or overload (e.g., excessive demands, Bills, 1943); an interfering response may increasingly reduce instrumental responding as the session progresses (e.g., Pavlov, 1928); responding may also change in anticipation of the end of the session, which entails, for example, free food in the home cage or the aversiveness of being handled. Finally, the reinforcer may lose its effectiveness because of satiation (e.g., Reese & Hogenson, 1962). In that case, however, the role of central and peripheral factors (taste, calories, etc.) in producing satiation would still have to be clarified.

This variety of potential explanations suggests, in turn, a variety of factors that may contribute to within-session changes in responding. It is unlikely that only one of these explanations will prove to be the single explanation for within-session changes. Instead, as will be discussed, several variables may contribute. Also, it must be recognized that these variables are not necessarily mutually exclusive. For example, improvements in "attention" might be accompanied by improvements in "memory." Finally, we do not wish to argue that these variables or interpretations are sufficiently well specified to be testable now. In particular, the behavioral implications of the cognitive terms noted above need to be specified before testing. As will be discussed, the predictions made by the "memory reinstatement" hypothesis will be different if current behavior is controlled only by the past experience of how to execute the response than if it is also controlled by the consequences of that response. Likewise, changes in "attention" might alter the degree to which behavior is controlled by the discriminative stimuli related to the task, or these changes might alter the animal's sensitivity to the response-reinforcer relation. The present review of the literature may help to clarify which of the many potential variables are operative in within-session change, and to specify their nature more precisely.

SELECTION OF DATA

In order to keep this review within manageable limits, several criteria were used to

select data. Results are reported only for non-human subjects responding in laboratory studies. Although responding changes systematically during sessions when human subjects are employed (e.g., Broadbent & Gregory, 1963; N. Mackworth, 1950), the literatures are too large to include both human and nonhuman subjects in the same paper. Data were sought from sessions that approximate the session durations used in most studies. Results were ignored if sessions were either extremely long (e.g., a day) or very short (e.g., 10 min).

Data are presented only if the experimental conditions were held constant across the session. Data were disregarded if an independent variable was changed at the beginning of the session or at some point during it. Changes in responding produced by these manipulations would distort the within-session changes in responding that are of interest here. Furthermore, transitional data were not considered. Thus, studies of acquisition and extinction, as well as studies that conducted only a few sessions or trials, were omitted.

Studies were considered only if they presented precise quantitative information and reported large and systematic changes in response rates. Cumulative records were disregarded, because many studies that report such records fail to present data for the entire session or involve changes in the experimental conditions at some point during the session. Also, although cumulative records clearly display abrupt changes in responding, gradual changes (such as those of concern here) may be more difficult to detect (Hineline, 1978b).

Even with these restrictions, this review should not be regarded as complete. Instead, enough examples are presented to illustrate the breadth of systematic changes in responding within sessions and to identify some of the conditions that produce these changes.

POSITIVE REINFORCEMENT

Schedules of Reinforcement

Table 1 summarizes the results of many studies that reported systematic within-session changes in positively reinforced responding under standard operant conditioning procedures. Studies are classified according to the type of reinforcer that was used (e.g., sucrose, milk, solid food, etc.). Standard terminology is

used in the table (continuous reinforcement, CRF; fixed interval, FI; fixed ratio, FR; variable interval, VI; differential reinforcement of low rates of responding, DRL; differential reinforcement of other behavior, DRO; concurrent, conc; lever press, LP). The change in behavior cited in the table is the most prominent change reported in a given study. For example, the studies by Collier are reported as showing decreases in responding across the session because that was their predominant finding. Bitonic functions do, however, occasionally appear in their data. If a behavioral change includes a hyphen, then the trend in responding changed within the session. For example, "constant-decrease" means that responding was constant early in the session and decreased later. If the behavioral change includes an "or," then the trend in responding was different during different experimental conditions. For example, "decrease or bitonic" means that responding decreased within sessions under some conditions but increased and then decreased under other conditions. Throughout this paper, the term *bitonic* will always refer to an increase in responding followed by a decrease.

Table 1 supports several general statements. First, within-session changes in responding occurred frequently. They occurred in behavior maintained by a wide variety of positive reinforcers, including several types of food, ethanol, water, light, electrical brain stimulation, and the opportunity to look out of the experimental enclosure. They occurred for a wide variety of species, including mice, rats, pigeons, goldfish, raccoons, rhesus and cebus monkeys, greater galagos, and slow loris. The changes in responding were also large. For example, Collier and Willis (1961) reported that rate of responding at the beginning of the session was more than eight times as high as at the end when a 64% sucrose solution was used.

Although almost all of the studies cited in Table 1 reported changes in rates of responding, a few other measures of behavior also changed systematically. In a laboratory simulation of foraging, Plowright and Shettleworth (1991) found that the acceptability of bad prey (an FI 12-s schedule), relative to good prey (an FI 2-s schedule), increased towards the end of a 20-min session. Elder and Nissen (1933) found that raccoons made more errors

Table 1

Studies that show systematic within-session changes in positively reinforced responding.

Study	Species	Response	Procedure	Change
Sucrose or milk				
Collier (1962a)	rats	LP ^a	FI 1 min	decrease
Collier and Bolles (1968)	rats	LP	FI 1 min	decrease
Collier and Myers (1961)	rats	LP	FI 1 min, FI 4 min	decrease
Collier and Siskel (1959)	rats	LP	FI 0.5 min to 4 min	decrease
Collier and Willis (1961)	rats	LP	FI 1 min, FI 4 min	decrease
Fobes, Ehrlich, Mukavetz, and Rodriguez-Sierra (1973)	slow loris	LP	aperiodic 35 s	bitonic
Fobes et al. (1973)	galagos	LP	aperiodic 35 s	constant- decrease
Hodos and Valenstein (1960)	rats	LP	VI 30 s	decrease or constant
O'Connell (1979)	rats	LP	DRO	increase
Premack (1961)	rats	LP	CRF	decrease
Schrier (1965)	rhesus monkeys	LP	CRF, VI 30 s	decrease
Solid food				
Antonitis (1951)	rats	response chain	CRF	decrease
Couvillon and Bitterman (1985)	goldfish	target contact	CRF	bitonic
Crossman et al. (1985)	pigeons	key peck	FR	decrease
Davenport and Gonzalez (1973)	rats	LP	CRF, VI 30 s	increase
Elder & Nissen (1933)	raccoons	alternation	trials	decrease
Hineline (1978b)	rats	chain pull	DRL	bitonic
Hutchinson and Renfrew (1967)	rats	LP	CRF	decrease or increase
Plowright and Shettleworth (1991)	pigeons	choice	FI 2 vs FI 12 s	increase
Schwartzbaum (1960)	rhesus monkeys	LP	FI 2 min	decrease
Willis et al. (1974)	rats	LP	conc food-water	decrease
Ethanol				
Heyman and Oldfather (1992)	rats	LP	VI	constant- decrease
Saccharin				
Collier (1962b)	rats	LP	FI 1 min, FI 4 min	decrease
Water				
Beck and McLean (1967)	rats	LP	VI 0.25 to 1 min	constant- decrease
Franklin and Quartermain (1970)	rats	LP	VI 1 min	increase
Gawley, Timberlake, and Lucas (1986)	rats	running, LP	burst constraint	bitonic
Grott and Neuringer (1974)	rats	LP	FR	decrease
Harvey and Hunt (1965)	rats	LP	CRF, DRL, FI	constant- decrease
Hendry and Rasche (1961)	rats	LP	VI 1 min	increase or bitonic
Hutchinson and Renfrew (1967)	rats	LP	CRF	decrease
N. Miller, Sampliner, and Woodrow (1957)	rats	LP	FIs alternated	decrease
O'Kelly et al. (1966)	rats	LP	FR 5 to 20	decrease- constant
Terhune (1978)	rats	LP	VI 40 s	decrease or bitonic
Willis et al. (1974)	rats	LP	conc food-water	increase

Table 1 (Continued)

Study	Species	Response	Procedure	Change
Electrical brain stimulation				
Fouriez, Hansson, and Wise (1978)	rats	LP	unspecified	decrease or bitonic
Hodos and Valenstein (1960)	rats	LP	VI 15 s	decrease or constant-decrease
Light onset or offset				
Kamback (1967)	rats	LP	unspecified	decrease
Kish and Baron (1962)	mice	LP	CRF	decrease
Premack and Collier (1962)	rats	LP	CRF	decrease
Premack and Putney (1962)	rats	LP	CRF + water	bitonic
C. Roberts, Marx, and Collier (1958)	rats	LP	unspecified	decrease
Tapp (1969)	rats	LP	unspecified	decrease
Tapp and Simpson (1966)	rats	LP or lever touch	CRF	decrease
Exploration or manipulation				
Premack (1963)	cebus monkeys	lever, plunger, door	CRF	decrease
Rabedaux and Miles (1959)	rhesus monkeys	window push	FI	decrease

* LP indicates lever press.

during the first half of their 30 trials per day than during the second half when choosing between boxes that sometimes contained food. Crossman, Trapp, Bonem, and Bonem (1985) reported that postreinforcement pauses and interresponse times were longer at the beginnings of sessions than later, when pigeons' key pecks produced food according to an FR 2 schedule. Finally, Antonitis (1951) reported that the variability in the location of a nose thrust by rats decreased with the number of reinforcers delivered, and therefore with the passage of time.

Table 1 shows that within-session changes occurred when a wide variety of schedules, including CRF, FI, FR, VI, DRL, DRO, multiple, and concurrent, were used. Changes have also been reported during laboratory simulations of foraging (Plowright & Shettleworth, 1991) and during second-order schedules (Hineline, 1972).

The forms of the changes in responding reported in Table 1 are somewhat difficult to interpret. Some differences may be by-products of the use of different intervals to average the data in different studies. For example, if responding increased for the first 15 min of the session and then decreased, a study that reported responding averaged over 5-min intervals would report that responding increased and then decreased within the session. A study

that averaged responding over 20-min intervals would report only a decrease. Enough studies are reported in Table 1, however, to support the conclusion that different patterns of responding are observed even when the same averaging procedure is used. In particular, increasing, decreasing, and bitonic patterns of responding are commonly reported.

The studies reported in Table 1 help to clarify the circumstances that produce these different patterns of responding. Terhune (1978) suggested that changes in instrumental behavior could be predicted from changes in unconditioned drinking. In his study, the probability of drinking by rats either decreased or increased and then decreased across 24-min sessions. When subjects were required to press a lever to drink, the rate of lever pressing showed the same pattern as drinking, and the correlation between the two responses always exceeded 88%.

The choice of response may be important. Franklin and Quartermain (1970) studied rats licking (Experiment 1) or pressing levers (Experiment 2), with water as the reinforcer in both cases. The mean number of licks per 5-min interval remained approximately constant across 20-min sessions, but the number of lever presses increased (see also Gawley, Timberlake, & Lucas, 1987).

Different schedules of reinforcement may

produce different changes in responding. This is most evident in a study by Palya (1992) that is not listed in Table 1 because of the complexity of its results. Palya studied pigeons' food-reinforced responding under a variety of schedules: FI, FR, VI, variable ratio (VR), DRL, and differential reinforcement of high rates of responding (DRH). Each of these schedules arranged approximately 60 reinforcers per hour. The postreinforcement pause decreased rapidly early in the session for the FR and DRH schedules, increased for the DRL schedule, increased and then decreased for the VI and VR schedules, and remained relatively constant for the FI schedules. Response rate increased over the first few reinforcers for the FR schedule; it decreased for the DRL schedule. Rate was relatively constant with a slightly increasing trend for the FI, VI, VR, and DRH schedules.

Deprivation and type of reinforcer may alter the changes in responding. Hutchinson and Renfrew (1967) reinforced rats' lever pressing with 45-mg Noyes pellets or 0.11 mL of water, available concurrently according to CRF schedules. When saline-injected subjects were deprived of food for 24 hr, food-reinforced responding decreased over successive 5-min intervals of the 30-min tests, but there was little water-reinforced responding. When subjects were deprived of water for 24 hr, water-reinforced responding decreased across the tests; food-reinforced responding increased (see also Willis, Van Hartesveldt, Loken, & Hall, 1974).

Patterns of responding may also be affected by the treatment that the subjects receive before the session. Hendry and Rasche (1961, Experiment 4) trained rats to press levers with water as the reinforcer. Their subjects were handled for 5 min before some sessions and were allowed to lick a stream of air for 1 hr before others. The rate of pressing increased during successive 4-min intervals of the 28-min tests when subjects were prehandled. Responding increased and then decreased with a final recovery late in the session when subjects were allowed to lick air.

Finally, Premack and Putney (1962) argued that the presence of a competing response can alter the pattern of responding within sessions. They showed that light-reinforced responding increased and then decreased when the opportunity to drink was also available. A similar study by Premack and Collier (1962) had re-

ported only a decrease in responding when subjects were not allowed to drink. Unfortunately, this conclusion requires a comparison of results across studies. Therefore, other procedural differences between the studies might account for the differences in results.

Simple and Complex Discrimination Procedures

At least two studies of simple discrimination indicate that responding to S+ (stimulus correlated with reinforcement) increases within sessions and responding to S- (stimulus associated with extinction) decreases (Tennant & Bitterman, 1973; Woodard & Bitterman, 1972). To give one example, Tennant and Bitterman reinforced striking at a target in the presence of one color (S+) and extinguished it in the presence of another color (S-). S+ and S- were reversed periodically. The subjects were goldfish, and the targets were presented alternately or randomly for 3-min periods, 20 presentations per session. The number of responses per stimulus presentation increased across the session for S+ and decreased for S-. Because these two studies sometimes conducted as many as five sessions between reversals and because they usually repeated each reversal several times, it is unlikely that the results are acquisition functions.

Two studies also reported changes in performance within sessions when pigeons responded on concept formation procedures. Herrnstein, Loveland, and Cable (1976) exposed pigeons to photographic slides for 80 trials per session. Pecking was reinforced in the presence of a slide that contained a particular feature that defined a concept for the experimenter (e.g., tree, water, person). In the presence of a slide that did not contain the particular feature, pecking was not reinforced and it delayed the offset of the next slide. Test sessions were conducted with novel slides after approximately 75 sessions of training. Fewer responses were emitted to slides presented later in the tests than to those presented earlier.

Vaughan (1988) designated some arbitrarily chosen slides as positive and some as negative. Responding was reinforced in the presence of the positive slides and not in the presence of the negative ones. These designations were reversed several times. During the session that preceded a reversal, in which performance was deemed stable, the average number of responses to each of the first 40 slides increased

for positive slides and decreased for negative slides.

The percentage of correct choices during delayed matching-to-sample tasks has also been observed to decrease (e.g., W. Roberts, 1980), increase (e.g., Edhouse & White, 1988), or remain constant (e.g., Wilkie, 1986) within sessions. Little is known about the factors that produce these differing changes. After applying a signal-detection model to their data, Edhouse and White concluded that improvements in the discriminability of the stimuli produced their improvements in performance. The rate of forgetting did not change across the session. Wilkie (1986) argued that performance was constant in his study because signaling the trials held attention constant across the session. However, there were too many differences between his and other studies to support this position conclusively.

Maze and Alley Studies

Studies of responding in alleys and mazes have reported within-session changes similar to those reported in Table 1. For example, Logan (1960) noted that rats usually run slowly on the first trial and fast on the second trial; then, speed declines over the remaining trials of the session. Other studies have reported that speed of running or swimming decreases across trials (e.g., Drew, 1939; Hill & Spear, 1962; Jensen & Cotton, 1960; Muntz, 1963; Renner, 1963). Still others have reported that speed increases (e.g., Gates & Allee, 1933; Melgren, 1972; Morgan & Fields, 1938; Tsang, 1938). The number of errors has also been found to increase (e.g., Tsang, 1938) or decrease across trials (e.g., Gates & Allee, 1933).

A few studies have examined variables that affect which pattern will be observed. Hill, Erlebacher, and Spear (1965) found that subjects initially exposed to trials without reward ran faster as the session progressed. Those not exposed to such trials ran slower. Examining the effects of different reinforcers, P. Young (1944) trained rats to shuttle from a start box to food located down an alley. With wheat in the goal box, the number of runs increased over the first 3 or 4 min of the 15-min tests and then remained constant. With sugar, the number of runs decreased across the session. Interposing a delay by confining the subject in the middle of the maze may also change the pattern of responding across trials (Cooper,

1938). For example, Gilhousen (1938) reported that rats ran faster across four trials per day when they were not thus confined. Speeds decreased across trials for subjects that were confined for 20, 30, or 60 s. The slope of the decrease was greater for longer delays.

More recent studies have reported that performance decreases across successive choices in a radial-arm maze. In one typical study, Olton and Samuelson (1976) placed rats in the center of a maze with eight baited arms. Subjects were given 10 min to collect the food. The probability of a correct response (entering an arm that had not been entered before) decreased with successive choices from approximately 100% to 75% to 80% correct. The decrease occurred regardless of whether these percentages were corrected for changes in the opportunity to make a correct choice with the number of previous choices. These decreases in accuracy with successive choices have been studied extensively. The present review will address only those findings that are directly relevant to our concerns.

To begin with, the decreases in accuracy occur quite generally. They have been reported for many species, but differences in the performances of different species have also been observed. Gerbils (e.g., Olton, 1978; Wilkie & Slobin, 1983) and ring doves (Wilkie, Spetch, & Chew, 1981) display behavior similar to that of rats. Pigeons are less accurate (e.g., Bond, Cook, & Lamb, 1981), but their performance can be improved by special training techniques (e.g., W. Roberts & Van Veldhuizen, 1985). Rats do not usually display simple patterns, such as entering alleys in a clockwise direction (e.g., Olton, Collison, & Werz, 1977), but other species (e.g., Siamese fighting fish) may engage in such patterns (Roitblat, Tham, & Golub, 1982).

Systematic changes also occur in other measures of behavior. Brown (1992) defined macrochoices as entering an alleyway and microchoices as orienting towards a particular arm. He found that the number of microchoices made prior to a macrochoice increased as a function of the number of arms previously visited. The probability of a correct macrochoice when the alley had been the target of a microchoice did not change as a function of the number of arms previously visited. Brown and Cook (1986) found that a statistic H , a measure of uncertainty, increased with the ordinal number of

the choice. They interpreted this to mean that response biases, such as turning clockwise, are more apparent in earlier choices. The time that subjects spent in the center compartment of the maze and the time that they spent in the arms also increased across choices. Brown (1990, Experiment 3) studied responding in a 16-arm maze with both long and short arms. The probability of entering a short arm decreased with the ordinal number of the choice. The probability of entering a long arm increased and then decreased.

When several trials are conducted per session, other measures of performance change systematically across successive trials. The number of choices required to reach a criterion either increases or increases and then decreases as a function of trial number (Dallal & Meck, 1990). The percentage of adjacent alleys entered increases across trials (W. Roberts & Dale, 1981, Experiment 1; Wilkie & Slobin, 1983). The number of errors, defined as entering an alley that has already been chosen, increases for rats (W. Roberts & Dale, 1981, Experiments 2 and 4), increases and then decreases for pigeons (Zentall, Steirn, & Jackson-Smith, 1990), and remains constant for gerbils (Wilkie & Slobin, 1983).

AVERSIVE STIMULI

Avoidance

In contrast to the many decreases in responding that occur when positive reinforcers are used (see Table 1), "warm-up" is the predominant finding for aversive stimuli. In escape or avoidance experiments, warm-up is an improvement in performance during the early part of the session with a loss of that improvement between sessions. This improvement may appear either as an increase in the rate of responding or as a decrease in the number of shocks received. Some studies report changes in both measures (e.g., Bersh & Alloy, 1980); some report changes in response rate without changes in shocks (e.g., Spear, Gordon, & Martin, 1973); and some report changes in shocks without changes in response rate (e.g., Powell, 1971).

Warm-up has been reported during escape procedures (e.g., Dinsmoor, 1962; Hendry & Hendry, 1963) and during avoidance procedures both with (e.g., Foree & LoLordo, 1970;

Hoffman et al., 1961) and without warning stimuli (e.g., Powell, 1970b; Wertheim, 1965). The changes in performance can be large. For example, Powell and Peck (1969) reported that rats received 60% to 80% of their total-session shocks during the initial third of the session. Warm-up is found for most, but not all, individual subjects (e.g., Weissman, 1962; but see also Foree & LoLordo, 1970). It also occurs at a rate that is characteristic for a particular subject (Hineline, 1978b), but that may vary widely from subject to subject (e.g., Badia, Culbertson, & Lewis, 1971).

Warm-up has been reported for escape from noise (e.g., Campbell, 1955) as well as from shock. It has been reported when responding controls the intensity of the shock as well as when it controls shock presentation (e.g., Bersh & Alloy, 1980). It has been reported for a wide variety of responses, such as key pecking (Foree & LoLordo, 1974), treadle pressing (e.g., Foree & LoLordo, 1970), lever pressing (Powell, 1971), shuttling (e.g., Kamin, 1963), rearing (Shishimi & Imada, 1977), and wheel turning (Gray, 1976). It has been found for unusual response requirements (e.g., Meltzer & Tiller, 1979). For example, Bersh and Alloy reported warm-up when shock duration was controlled by responses within a limited range of interresponse times.

Warm-up has been found for several species, including pigeons (e.g., Foree & LoLordo, 1970), gerbils (Powell & Peck, 1969), and many types of rats (e.g., Powell, 1971, 1972, 1976; Powell & Mantor, 1970). It is not found for all species, however. For example, it is absent or weak in goldfish (Scobie, 1970). It is also larger for domesticated rats (such as albinos and hoodeds) than for semidomesticated rodents (such as black or cotton rats and gerbils; Powell, 1971, 1972).

Warm-up is observed early in avoidance training (e.g., Spear et al., 1973). It is also specific to avoidance responses. For example, it does not occur for responding during the intertrial interval (Nakamura & Anderson, 1962). Strangely, warm-up need not occur in all avoidance responses. Sidman (1962) placed rats in a concurrent two-lever avoidance situation. One rat showed warm-up on one lever while responding at a consistently high rate on the other.

Although warm-up has received the most attention in the avoidance literature, constant

or decreasing responding has also been reported when subjects escape from light (Jerome, Moody, Connor, & Ryan, 1958). Biotonic functions have also been reported in studies of shock avoidance. For example, G. Young and Black (1977, Experiment 1a) reported that, when rats could avoid shocks by licking a 10% sucrose solution, performance improved early in 40-min sessions and decreased later. This was particularly true when the subjects had been deprived of water for 22 hr. Rats that avoided shocks by pressing levers (Experiment 1b) showed relatively constant responding when water deprived and a small, but statistically significant, warm-up when satiated.

A few factors are known to influence the size and occurrence of warm-up for avoidance. The most extensively studied is the pretreatment of the subjects. Warm-up is not reduced by confinement in the experimental enclosure before the session (Hoffman et al., 1961), but it can be reduced or eliminated by presenting free shocks (e.g., Hoffman et al., 1961; but see also Gray, 1976) or by pairing the stimulus with shock in discriminated avoidance (e.g., Spear et al., 1973). At least one study contained some important controls. Spear et al. showed that pretreatments with shock or stimulus-shock pairings did not change responding early in the session when given to subjects that had not received avoidance training. They also showed that the pretreatment changed early-session responding only when delivered immediately before the test, not when given as "overtraining" at the end of the previous learning session.

Warm-up is altered by changing the time between sessions (e.g., Kamin, 1963). For example, Hineline (1978b) reported that warm-up does not appear during the second session if two avoidance sessions are given in a row, but it gradually reappears when the sessions are separated by 30 to 360 min. Inserting a timeout in the middle of the session also produces warm-up during the second half (Hineline, 1978b). The size and duration of the second warm-up increase systematically with increasing timeout durations from 0 to 30 min. Under some conditions, rats may show greater warm-up in the second than in the first half of the session.

The effect of shock intensity is not clear. Some studies have found that changing inten-

sity alters warm-up (e.g., Leander, 1973); others have found that it does not (e.g., Hoffman et al., 1961; Powell, 1970b). Shock frequency also exerts little control over the size of warm-up (e.g., Hineline, 1978a) but it does alter performance later in the session.

Punishment

Increases in responding early in the session are also observed during punishment procedures (e.g., Azrin, 1956, 1960; Azrin, Holz, & Hake, 1963; Hake & Azrin, 1965; Hake, Azrin, & Oxford, 1967). Warm-up in punishment experiments has not been studied as extensively as warm-up in avoidance experiments, but it has been found for pigeons (Powell, 1970a), squirrel monkeys (Hake et al., 1967), rats (Appel & Peterson, 1965), and mice (Baron & Antonitis, 1961). It is found for responding supported by simple schedules (e.g., Azrin, 1960) as well as by multiple schedules (Powell, 1970a). It occurs when the punished behavior is unconditioned (Baron & Antonitis, 1961) as well as when it is conditioned. It is found in studies of unconditioned (e.g., Azrin et al., 1963) as well as conditioned (Hake & Azrin, 1965) punishment. It is most pronounced at intermediate (6.7 and 12 mA) punishment intensities (Powell, 1970a) and, like warm-up for avoidance, it is restored by a timeout from the schedule (Azrin, 1960). Finally, warm-up persists for several sessions after punishment is discontinued.

UNCONDITIONED BEHAVIOR

Large within-session decreases in unconditioned behavior patterns are often reported. Decreases have been reported in consummatory responses (such as eating and drinking; e.g., Rachlin & Krasnoff, 1983), in responses that are evoked by stimuli (e.g., habituation, R. Thompson & Spencer, 1966), and in "spontaneously" occurring behavior patterns (such as activity, locomotion, and exploration; e.g., Montgomery, 1953a, 1953b). Most of these changes will not be discussed because the literatures are too vast and have been reviewed elsewhere (e.g., Groves & Thompson, 1970; R. Thompson & Spencer, 1966). Instead, we will focus on two points.

First, although unconditioned behavior pat-

terns usually decrease across the session, increases (e.g., Montgomery, 1955) or bitonic functions have also been reported (Bindra & Spinner, 1958; Blanchard & Blanchard, 1971; Bronstein, Neiman, Wolkoff, & Levine, 1974; Chiszar, Wellborn, Wand, Scudder, & Smith, 1980; Davis & Astrachan, 1978; Schnur & Martinez, 1989; W. Thompson & Solomon, 1954). For example, Davis (1974a, 1974b) reported that startle responses elicited by a tone decreased with successive tone presentations when the tone was 120 dB, regardless of background noise. Responses to a 110-dB tone decreased when the background noise was 60 dB, remained unchanged if the background was 70 dB, and increased and then decreased when the background was 80 dB. This bitonic function was found in each of 6 days of testing for a given animal.

Second, systematic changes have been reported in the responses that are used in conditioning procedures, even in baseline conditions when no reinforcement is presented. For example, unconditioned lever pressing decreases within sessions for rats (Schoenfeld, Antonitis, & Bersh, 1950); it increases and then decreases for mice (Antonitis & Baron, 1961; Baron & Antonitis, 1961). Changes in deprivation may alter the form of these changes. Segal (1959) reported a decreasing function for satiated rats and a bitonic function for rats that were deprived of food or food and water for 23.5 hr prior to testing.

The length and type of confinement prior to testing also contribute. Unconditioned lever pressing increases and then decreases across a 60-min session for subjects kept in a large box for 0 or 5 min or in a small box for 5 or 65 min prior to the test (Baron, Antonitis, & Beale, 1961). Responding decreases across the session for subjects kept in a large box for 65 or 125 min. Finally, responding is relatively constant for subjects confined in a small box for 125 min.

CONCLUSIONS

Empirical Summary

Systematic changes in responding within sessions are not confined to the use of one particular type of procedure, species, reinforcer, or laboratory. Instead, these changes have been reported in studies of positive re-

inforcement, avoidance, punishment, extinction, discrimination, concept formation, delayed matching to sample, maze and alley running, and laboratory analogues of foraging. Changes also occur in the unconditioned substrates of conditioned behavior. These changes have been reported for many species of subjects, including cockroaches, snakes, goldfish, gerbils, hamsters, wild rats, raccoons, greater galagos, and slow loris, as well as standard laboratory pigeons, mice, rats, and monkeys. The changes have been reported in procedures using several different reinforcers, such as food, ethanol, water, light, shock, noise, and the opportunity to look out of the experimental enclosure. Systematic changes have also been reported for a number of different dependent variables, including response rate, postreinforcement pause, response accuracy, response effectiveness as measured by shock rate in avoidance, and acceptability of bad prey items.

Taken together, these results suggest that within-session changes in responding are a relatively general property of animal behavior. Only a few data limit their generality. First, systematic changes have not been reported for all dependent variables. To date, changes have not been reported for the duration of lever pressing or licking (e.g., Collier & Myers, 1961, but see also Collier, 1962a) nor for the latency of responding (e.g., Fath, Fields, Malott, & Grossett, 1983).

Second, some studies report relatively constant performance, even in measures of behavior that were observed to change in other studies (e.g., Bloomfield, 1967; Hutt, 1954; Wesp, Lattal, & Poling, 1977; Wheatley & Welker, 1977). Unfortunately, the relative frequency with which responding changes and remains constant cannot be estimated from the literature, because authors have little reason to report constant responding.

Responding has been shown to increase, decrease, or increase and then decrease across sessions in different situations. A few factors alter the form of the function. For example, in the case of positive reinforcement, the schedule of reinforcement (Palya, 1992) and the nature of the reinforcer (e.g., P. Young, 1944) may change the shape of the within-session function. Increases in responding (warm-up) are also particularly likely to occur when aversive stimuli are used.

The treatments that subjects receive before

the session may contribute. Changing the pre-treatment changes the form of the function for unconditioned lever pressing (Baron et al., 1961) as well as for responding reinforced with food (Hineline, 1972), water (Hendry & Rasche, 1961, Experiment 4), or shock avoidance (Hoffman et al., 1961; Spear et al., 1973).

The subject's state of deprivation may alter the form of the function that describes responding reinforced by deliveries of food (Davenport & Gonzalez, 1973; Hodos & Valenstein, 1960; Hutchinson & Renfrew, 1967; Kohn, 1951; Willis et al., 1974), saccharin (Collier, 1962b), water (Hutchinson & Renfrew, 1967; Willis et al., 1974), electrical brain stimulation (Hodos & Valenstein, 1960), and shock avoidance (e.g., G. Young & Black, 1977). Food and water deprivation can also change the form of the function for unconditioned lever pressing (Segal, 1959).

Finally, the occurrence of a delay can alter the form of the function. In general, interposing a long enough delay either within or between sessions returns responding to the state that it occupied at the beginning of the session. This has been shown when responding produces food (e.g., Gilhousen, 1938), avoids shock (Hineline, 1978b; Kamin, 1963), or is punished (Azrin, 1960).

Theoretical Implications

Except for a few experiments on warm-up in avoidance (e.g., Spear et al., 1973), the studies reviewed were not explicitly designed to evaluate different theoretical explanations for the changes in responding. Therefore, the literature does not compel theoretical conclusions as much as it suggests directions for future research. Before discussing these directions, however, it should be noted that the same factors probably do not produce all of the changes. For example, warm-up in avoidance may be more than one effect. Changes in responding are sometimes reported without changes in the number of shocks received, and vice versa. Therefore, different factors may produce warm-up in avoidance responding and warm-up in avoidance shock rate.

The discussion below will assume that different factors produce the increases and decreases in responding, because each of these changes has been observed without the other (see Table 1). This suggests that the two limbs of the bitonic function are produced by differ-

ent factors and that bitonic functions emerge when both types of factors are present.

Positive Reinforcers

The studies reviewed suggest that at least two different variables contribute to decreases in positively reinforced responding (e.g., Collier & Myers, 1961). One variable is related to the presence of strong reinforcers (e.g., satiation). For example, many studies show that responding decreases or decreases more steeply when larger or stronger reinforcers are delivered at higher rates (e.g., Beck & McLean, 1967; Collier, 1962b; Collier & Bolles, 1968; Collier & Myers, 1961; Collier & Willis, 1961; Couvillon & Bitterman, 1985; O'Kelly, Crow, Tapp, & Hatton, 1966; Premack, 1961; Schwartzbaum, 1960; Segal, 1959; Willis et al., 1974). The other variable is related to weak or absent reinforcement (often interpreted as loss of motivation or attention). For example, responding decreases during extinction and during the S- in discrimination tasks. It decreases for unconditioned behavior and when relatively weak reinforcers (such as lights) are used.

The precise natures of the variables that produce decreases in responding remain to be clarified. For example, the concept of satiation is complex, and results presented by Collier (1962b) indicate that the presence of calories is not necessary to produce this "satiation." Collier reported satiation-like results—that is, responding decreased more steeply within the session when highly concentrated reinforcers were delivered. However, because saccharin served as the reinforcer, the accumulation of calories cannot account for these decreases.

Likewise, the factor that is related to weak or absent reinforcement may be either motivational or attentional, but some results favor an interpretation in terms of attention. For example, Table 1 shows that for rats, responding usually decreases within sessions of sucrose-reinforced responding. The only exception occurred in a study that employed a DRO procedure (O'Connell, 1979). The increase in responding within the session reported by O'Connell is obviously incompatible with any theory that predicts little responding late in the session (e.g., decreases in motivation or arousal). In contrast, the increase is compatible with theories that predict that subjects become progressively less sensitive to the contingencies

as the session progresses (e.g., loss of attention). More pressing means less sensitivity to a DRO contingency. Future studies should attempt to replicate these results. At present, this conclusion is only weakly supported because it relies on a comparison of results across studies.

Finding that responding decreases under conditions of minimal and strong reinforcement does not rule out the possibility that other factors (such as fatigue, interfering responses, and anticipation of the end of the session) also contribute. However, contributions of such factors have not been established at this time.

The literature also supports some conclusions about the factors that produce within-session increases in positively reinforced responding. To begin with, recovery from handling cannot be a complete explanation. Within-session changes in responding have been observed even when subjects are not handled before the session (e.g., Montgomery, 1955).

Responses with the potential to interfere have been observed during the early parts of sessions, and they disappear later (e.g., Tapp, 1969). Different distributions of responding have also been reported in the presence and absence of a potentially interfering response (cf. Premack & Collier, 1962, to Premack & Putney, 1962). However, these data provide only weak support for interfering-response theories, at least with respect to positively reinforced behavior. The first types of data are correlational. They show that potentially interfering responses occur when instrumental responding is low. They do not show that interfering responses produce weak instrumental responding. The second types of data require comparing results across studies. Such comparisons are risky, because procedural differences between the experiments may actually account for the differences in results.

In contrast to this weak support, stronger data question both the disappearance of interfering responses and increases in arousal (e.g., Killeen et al., 1978) as explanations of warm-up for positive reinforcement. As argued earlier, studies of discrimination and concept formation (e.g., Tennant & Bitterman, 1973; Vaughan, 1988; Woodard & Bitterman, 1972) have reported that responding increases during S+ and decreases during S- as the session progresses. If increasing arousal produces more

responses, then these extra responses should be observed during both S+ and S-. The disappearance of an interfering response should allow responding to increase across the session during extinction as well as during reinforcement.

Finding increasing responding during S+ and decreasing responding during S- is particularly consistent with explanations of warm-up for positive reinforcement in terms of increasing attention (e.g., Irion, 1948) or reinstatement of memory (e.g., Spear, 1973) for the stimulus-response-reinforcer contingency. In either case, subjects might become increasingly more sensitive to the contingencies of reinforcement during the early part of the session. This explanation is also compatible with results reported by Edhouse and White (1988). They reported that measures of discrimination improved within sessions during a delayed matching-to-sample procedure. If "attention" improves, then behavior should come increasingly under the control of the relevant discriminative stimuli, as reported. In contrast, motivational explanations for the early improvements in performance do not clearly predict that discrimination should change within sessions.

Finding that a variable related to attention may contribute to the increases in responding does not rule out the possibility that other variables also contribute. For example, the increases in responding during S+ in a discrimination procedure are also consistent with the idea that positive reinforcers may gain in strength during the early part of the session (e.g., priming). The decreases in responding during S- could be attributed to the previously discussed factor that produces the decrease in responding under conditions of minimal reinforcement (e.g., loss of attention).

Aversive Stimuli

The observation of early-session increases in responding during punishment procedures is not compatible with the idea that sensitivity to or memory for a punishment contingency improves, or that the punishers become increasingly effective as the session progresses. Any of these variables would produce a decrease, not the observed increase, in responding early in sessions of punishment. Instead, increased responding during the early parts of sessions of both punishment and avoidance

suggests that instrumental responding is weak early in sessions that employ aversive stimuli. These results are compatible with theories that explain warm-up for aversive stimuli in terms of increasing arousal (e.g., Hoffman et al., 1961), decreasing interfering responses (e.g., Hineline, 1966), or reinstatement of memory (e.g., Spear, 1973) so long as the memory includes how to respond but not the consequences of that responding.

This argument suggests that different factors predominate in different types of situations that produce within-session increases in responding. When positive reinforcers are involved, the within-session changes seem to be attentional in character; when aversive stimuli are involved, the changes seem more motivational in character. Future experiments should explicitly address this possibility. Finding that different factors are involved may eventually complicate the formulation of a unified theory of reinforcement and punishment. Alternatively, the results for positive reinforcement may appear only under restricted circumstances. Several of the studies that supported the present explanations for the increases in responding for positive reinforcers employed a discrimination-reversal procedure. Although several sessions were conducted between reversals, such procedures may not produce truly stable responding; therefore, their results may not be relevant here. These procedures may also favor development of performance in which animals respond similarly to both S+ and S- early in the session and then change their responding when the contingencies become clear. Such a strategy would ensure that the task is quickly mastered when a reversal occurs. In that case, within-session changes in responding might be produced by increasing sensitivity to contingencies only under the limited conditions in which the procedure favors such a response pattern.

POTENTIAL THEORETICAL IMPLICATIONS

Within-session changes in responding deserve further study because they have both potential theoretical and methodological implications. First, these changes challenge both molar and molecular theories of behavior. Within-session changes challenge molar the-

ories because they imply that the primary dependent variable used by these theories, the rate of responding averaged across the session, is too gross to produce an adequate understanding of behavior. The use of such a measure will neglect systematic variations in behavior that are clearly evident at a more molecular level. Within-session changes challenge molecular theories because these theories attempt to predict moment-by-moment changes in responding, and thus are obligated to account for systematic within-session changes in responding.

Second, the study of within-session changes in responding may help to clarify some theoretical controversies. For example, some theories predict that the response rate will increase as a monotonic function of the rate of reinforcement (e.g., Herrnstein, 1970). Other theories predict that responding will increase and then decrease (e.g., Baum, 1981; Staddon, 1979). The question arises whether monotonic increases would be found if factors that changed over the session were prevented. McSweeney (1992) showed that they would. Responding during the first 5 min of the session increased monotonically with increases in the rate of reinforcement. Responding later in the session declined at the highest rate of reinforcement. Therefore, different theories made correct predictions, depending on the time at which response rates were measured (see also Collier & Myers, 1961).

Third, within-session changes in responding indicate a need for reevaluating several traditional theoretical concepts. For example, the concept of "acquisition" should be reexamined. Responding frequently improves within early sessions of training. The usual explanation for this improvement is that the animal is learning about the situation. R. Miller (1982) suggested that better utilization of previously acquired information may also contribute. The present results may add a third factor. McSweeney (1992) showed that responding during the first session of operant training follows a bitonic function similar, but not identical, to the bitonic changes in responding at asymptote. This suggests that some of the improvements in performance during acquisition also occur and for whatever reasons, produce the increases in responding observed in the early parts of operant conditioning sessions.

The concept of "spontaneous recovery" should also be reexamined. Spontaneous recovery refers to the recovery of an extinguished response at the beginning of the next session. Most theories of extinction have had difficulty explaining this recovery without adding special assumptions. For example, Pavlov (1927) argued that responding recovered because inhibition dissipated between sessions. The literature reviewed here suggests that the difficulty in explaining spontaneous recovery occurs because spontaneous recovery is not specifically a characteristic of extinction. Instead, spontaneous recovery may occur during extinction only because extinction presents factors that produce systematic decreases in responding within sessions.

This interpretation suggests that spontaneous recovery should be observed whenever conditions are present that produce a decreasing pattern of responding, a prediction that has been confirmed. To date, responding has been seen to recover between sessions for unconditioned lever pressing (e.g., Schoenfeld et al., 1950) and for responding that is undergoing positive reinforcement (e.g., Hill et al., 1965; Hill & Spear, 1962; Jensen & Cotton, 1960; Renner, 1963). Thus, spontaneous recovery is not specific to extinction but is a characteristic of behavior in several situations. To understand spontaneous recovery, we need to understand more generally the factors that produce within-session changes in responding.

A third concept that requires reexamination is "proactive interference." Studies that employ memory procedures, such as delayed matching to sample, frequently attribute decreases in performance to proactive interference (e.g., Edhouse & White, 1988; Jitsumori et al., 1989; Zentall et al., 1990). That is, they argue that information from past trials interferes with performance on the present trial. The present review shows that responding may decrease within sessions even when the task is not specifically a memory task (e.g., lever pressing maintained by sucrose as the reinforcer). Finding such decreases suggests that care should be taken before ascribing decreases in responding to proactive interference. This is not to say that the concept has no use. A broadening of the concept might even allow it to explain the decrease in responding maintained by sucrose. However, for now, results should not be attributed to proactive interfer-

ence without more evidence than the simple observation of a decrease in performance.

POTENTIAL METHODOLOGICAL IMPLICATIONS

Methodologically, within-session changes in responding imply that studies should be designed to avoid confounding these changes with the effect of their independent variable. For example, when studying the effect of rate of reinforcement on rate of responding, the experimenter must either confound session length or number of reinforcers delivered per session with rate of reinforcement. Session length is often confounded (e.g., Catania & Reynolds, 1968) because confounding the number of reinforcers might produce systematic changes in "satiation." However, McSweeney (1992) showed that the peak rate of responding occurs at approximately the same time regardless of session length. Therefore, comparisons of different procedures of different lengths may sample different parts of the within-session changes in responding, yielding different average response rates.

Within-session comparisons of different procedures should also be used with caution (e.g., Heyman, 1983; McSweeney & Melville, 1990; Staddon, 1967). To be sure, presenting different aspects of an independent variable in different parts of a single session rather than in different sessions can be useful, because the large shifts in the baseline response rates that can occur from day to day do not add variability to the data (e.g., McSweeney, Dougan, Higa, & Farmer, 1986; Speelman & Gollub, 1974). Furthermore, the procedures save time because all values of the independent variable are conducted at once, rather than successively. However, the effect of the independent variable will be difficult to interpret if these procedures present different values of their independent variables at times within the session that control different response rates. Because the generality, the size, and the factors that govern within-session changes in responding are not known, the precise limitations of within-session procedures are also not yet known.

Experiments should not be conducted so that they deliver one number of trials per session and report the data in units of a different number of trials. This practice will not create problems if data are reported in multiples of whole

sessions, but it will be problematic if data are presented in terms of fractions of sessions (e.g., Franchina & Billig, 1978; Kehoe & Holt, 1984) or in terms of moving averages that sample different parts of the session at different times (e.g., Ghiselli & Fowler, 1976). At the very least, averaging over different parts of the session at different times may add variance to the data. At worst, within-session changes in responding per se may be confounded with changes that are attributed to the independent variable.

Changes in responding within sessions imply that all experimenters studying a particular phenomenon should use the same duration of adaptation period if such a period is used at all. If subjects begin advancing on the within-session function as soon as they are placed in the chamber, then experiments that use adaptation periods of different lengths will intersect the function at different points, introducing a confounding variable. It is not known whether this occurs. Some experiments suggest that giving adaptation periods of different durations may alter responding during the session (e.g., Davis, 1974a, Experiment 3; Thomas & Burr, 1969), and some suggest that they do not (e.g., Jenkins, Barnes, & Barera, 1981; Marlin & Miller, 1981). However, until this issue is settled, experimenters attempting to replicate systematically the findings of others should use the same durations of adaptation periods unless they are certain that the duration of that period does not alter responding during the situation under study.

SUMMARY

Within-session changes in responding have frequently, but not always, been observed when subjects respond on a number of procedures. Responding during avoidance and punishment procedures usually increases early in the session. Positively reinforced behavior changes in a variety of ways, including increasing, decreasing, and bitonic changes. Although it requires further study, some evidence suggests that the disappearance of interfering responses, increased strength of the response itself (perhaps interpretable as remembering), or increases in arousal may account for the early increase in responding during aversive procedures. Other evidence suggests that increases in sensitivity to or memory for the re-

sponse-reinforcer contingency, or increases in the effective strength of the reinforcer, may contribute to increases in positively reinforced responding. At least two factors may contribute to decreases in positively reinforced responding. One occurs when strong reinforcers are presented at a high rate (e.g., satiation). The other occurs when reinforcers are weak or absent (e.g., loss of attention). Bitonic functions may be observed when the factors that produce both increases and decreases in responding are present. Constant responding may be observed when the factors do not occur or cancel each other's effects.

Regardless of their theoretical explanation, the observation of within-session changes in responding should affect our reporting of experiments as well as the problems that arise in interpreting their data. Further experimental analyses that specifically address these changes should refine our understanding of when they occur, as well as their theoretical explanation. Because systematic changes in responding have been observed during many procedures outside of the field of conditioning (e.g., vigilance performance, human work curves), these changes may also have implications for psychology in general.

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